AN EXPERIMENTAL ANALYSIS OF THE PAPER-REINFORCED BAR PRESSING BEHAVIOR OF THE GOLDEN HAMSTER (MESOCRICETUS AURATUS)

By

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Major Department: Psychology

A series of experiments was conducted using operant conditioning techniques to study the nesting behavior of the golden hamster (Mesocricetus auratus). Presentation of a 3 cm. strip of paper served as the response-contingent event (reinforcement), and the schedules of reinforcement that were used included fixed-interval, variable-interval, fixed-ratio, progressive-ratio, and differential reinforcement of low rate (DRL) schedules. In addition, multiple fixed-ratio--fixed-ratio and multiple variable-interval--variable interval schedules were studied, with paper and food reinforcement alternating with changes in the schedule components. Both male and female hamsters were used in these experiments.

Cumulative records of the performance of thirteen hamsters indicated that paper delivery can be used as a positive reinforcer for establishing and maintaining schedule-controlled patterns of responding in the hamster under a wide variety of experimental conditions.

When progressive-ratio schedules of food and paper delivery were used to investigate the relative reinforcing strength of these two positive reinforcers, hamsters consistently responded to higher terminal ratios for food than they did for paper. This phenomenon was observed in animals that were not food-deprived, and, in general, food-deprivation was not found to be a necessary condition for establishment of food-maintained operant behavior in the hamster. The results of these experiments were discussed in terms of the environmental stimuli (accumulated food and nesting material) that may have physiological significance for hibernation in the hamster.

INTRODUCTION

In the series of experiments to be described below, two lines of behavioral research converge. Both are related to the psycholog concept of "Reinforcement", which forms the basis of many theories behavior, development, and learning. The two research topics to be presented are species-specific or "instinctive" reinforcement, and schedule effects of reinforcement. More specifically, the experiments are concerned with a) nesting material as a species-specific reinforcer for the golden hamster, and b) the effects of scheduling the presentation of nesting material in consistent temporal patterns (interval schedules), or after particular quantitative work requirements have been met (ratio schedules). The experiments have been designed with the intention of adding generality to other data collected using traditional positive reinforcers (food and water). Also, when the findings of these experiments deviate from conventional results, an attempt will be made to interpret these differen and consider their significance.

Reinforcement

When the response-dependent presentation of an event is sufficient to establish and maintain a new response in the repertoire of an organism, that event is termed a "positive reinforcer". Food presentation to a food-deprived organism is such an event, as is water presentation to a water-deprived organism.

Positive reinforcers such as food and water have long been used by psychologists to develop and maintain a broad range of lea behavior patterns. Many psychological theories have been developed on the basis of the results of experiments using food and water as positive reinforcers. Hypothetical psychological processes such as drive reduction, need reduction and tension reduction have been postulated to explain these results (Kimble, 1961).

Species-typical Reinforcement

Many types of environmental events are known to function as positive reinforcers within a species or genus. For example, when a lever press unlocked a running wheel for 30 seconds, albino rats in the wheel maintained higher response rates on the lever than did rats with levers that were inoperative (Kagan and Berkun, 1954). Rhesus monkeys achieved and maintained a level of nine out of ten correct panel presses when the result of the correct response was the opportunity to view an active laboratory area for 30 seconds (Butler, 1953). Deermice (*Peromyscus*) pressed a lever which released sand into an accessible area of the experimental chamber, and response rates on this lever were higher than rates on a second lever which did not produce sand (King and Weisman, 1964).

In all of the above cases, reinforcers were demonstrated to function in situations that were unrelated to primary "drives" or "needs". Thus, while food and water are almost universally accepted as reinforcers across species, it is also true that other events can function as reinforcers of equal behavioral significance, though with less cross-species generality.

Schedules of Reinforcement

Another property of positive reinforcers emerges when these events are scheduled in a consistent manner: responses are emitted in temporal patterns that are replicable with individual organisms and across species (Ferster & Skinner, 1957). Recent work by Kelleher and Morse (1969) and Byrd (1969) has emphasized the importance of the schedules of event presentation as fundamental determinants of behavior. Characteristic fixed-interval and fixed-ratio patterns of responding (Ferster & Skinner, 1957) were maintained by response-produced electric shock in squirrel monkeys and cats with appropriate experimental histories. These response patterns were indistinguishable from the patterns produced when food or water was the contingent event. Morse and Kelleher (1970) have argued that comparable schedule-controlled patterns of responding maintained by different types of events attests to the equivalence of these events as reinforcers. Thus reinforcers are defined as such in terms of their ability to maintain behavior in particular situations or on particular schedules. "Common sense" definitions of reinforcers are at best incomplete until experimental evidence is provided to determine _under_ _what_ _conditions_ event (X) is a positive reinforcer.

Uses of Scheduling Techniques

Scheduling techniques were developed by Skinner (1938) and his students in opposition to the generally accepted tradition of the Behaviorists who used rats in mazes to study the behavior of organisms (e.g., Tolman, 1932; Hull, 1943). Maze studies typically provided data on behavior maintained by the two most simple schedules of reinforcement, continuous reinforcement (correct goal box) and extinction, or no reinforcement (incorrect goal box). While the data from these studies were undeniably valid, their generalizability across reinforcers and across species suffered because of the particularly narrow range of reinforcing contingencies actually studied.

As was noted above, there are two major types of schedules of reinforcement, interval schedules and ratio schedules. These two categories are, in turn, further subdivided into fixed and variable interval schedules (FI, VI) and fixed and variable ratio schedules (FR, VR). Each of these four "basic schedules" of reinforcement produces a characteristic pattern of responding when they are used to establish and maintain a simple, arbitrary operant response such as bar-press in the repertoire of an organism.

There are three main reasons for using schedules of reinforcement to study behavioral phenomena. First, schedules of environmental events such as circadian rythms or weekly paychecks exert considerable influence in the day-to-day life of all animals, man included. Second, schedules of reinforcement, including their interactions and by-products, can be used to uncover new information about the ways in which complex behavioral sequences can be understood in terms of their consequences (Findley, 1962). Finally, schedules of reinforcement can be combined with automated programming and recording equipment to allow researchers to study behavior using chronic, long-term paradigms (Mason, Brady, and Tolliver, 1968).

Some concrete examples of the uses of scheduling techniques can be drawn from the research of Teitelbaum and of Falk, who were studying operant behavior maintained by food and water reinforcement. Each of these researchers made discoveries that would have been impossible if the more simplistic approach of the traditional maze experiments (continuous reinforcement or no reinforcement) had been used.

Teitelbaum (1957) showed that by using fixed-ratio schedules of food reinforcement it became quite easy to discriminate between normal, food-deprived rats and hypothalamic-hyperphagic rats, with the normal rats working reliably on schedules as high as fixed-ratio 256, while the hyperphagic rats would usually cease responding when the fixed-ratio requirement went higher than fixed-ratio 16. Experimental findings using various schedules of food and water reinforcement have also provided a considerable body of information on the homeostatic processes involved in feeding and drinking and their interrelationships that would have been otherwise unavailable. For example, Falk (1961) demonstrated that when rats work for food on a variable-interval schedule they drink three to four times their normal daily water requirement during a three-hour work session. This phenomenon, termed "schedule-induced polydipsia", is just one of many demonstrations that the work requirements of a particular schedule can have profound effects on other behaviors not directly related to the reinforcement schedule in effect.

Once the potential usefulness of the scheduling techniques is established, specific experiments employing them can be designed. In the series of experiments to be presented below, scheduling techniques were used to study the nesting behavior of the golden hamster. Before describing the actual experiments, some information about golden hamsters will be provided. Also, data collected in other studies of nesting behavior will be discussed and criticized.

The Golden Hamster

The golden hamster (Mesocricetus auratus) is a desert-dwelling rodent of the family Cricetidae, subfamily Cricetinae. The hamster lives a solitary life except for mating, lactation, and the first few weeks of life. Adult hamsters are known to establish and defend territories, which they "mark" by rubbing their flank scent glands against objects in their environment. If two hamsters are forced to live together, they will develop dominance-submission behavior patterns that are quite stable over time (Grant & Mackintosh, 1963).

Hamster are also known to dig burrows, to hibernate, to "hoard" large quantities of food, and to build nests in their burrows. Both male and female hamsters build nests, and when they are gathering nesting material they typically insert the material into their large cheek pouches before depositing it at the nest site.

Nesting Behavior

The literature dealing with nesting behavior that will be reviewed in this section will be confined to experiments on mammalian nesting behavior since the experiments to follow are a study of the nesting behavior of a particular mammal, the golden hamster (Mesocricetus auratus).

Nesting behavior, in a functional sense, is one variety of behavioral thermoregulation commonly employed by small animals. Thermoregulation is a topic of particular significance in the life-cycle of all mammalian species, and this significance is reflected by the fact that both physiological and behavioral systems have evolved in the service of thermoregulation (Prosser & Brown, 1961).

Most of the studies of nesting behavior that have appeared in the animal literature have used a free-access procedure in dispensing the nesting materials to the animals. Quantification of the nest-material-acquisition process has taken several forms over the years. Kinder (1927) allowed rats to accumulate strips of crepe paper that were hanging over the edge of their cage, and then counted the number of strips used. Richter (1942) used a continuous, narrow roll of paper and recorded how many cm. of paper the rats pulled from the roll in a given time period. In more recent experiments, Denenberg and his co-workers have developed a method of quantification of rabbit nesting behavior. Their technique employed 48 small cans, each containing a "wad" of excelsior, and they measured how many wads were removed in a 24-hour period, and how many were shredded (Denenberg, Huff, Ross, Sawin, and Zarrow, 1963). Denenberg's group has also developed nesting-quantification procedures for the rat. In one study, wooden dowels were placed in the rat's cage, and the amount of wood shredded daily was used as a measure of nest building (Denenberg, Taylor and Zarrow, 1969). In quantifying the nesting behavior of hamsters, Richards (1969) weighed the amount of straw an animal pulled into its cage in a 24-hour period (free access). Layne (1969), in studying the nesting behavior of three species of deermice Peromyscus, used two methods of quantifying nesting behavior, both of the free-access variety, with the mice pulling cotton into their cages from a can on top, or pulling in paper strips that were hung over the edge of the cage. Layne took daily measures of the amount of paper shredded, the amount of cotton taken, and the type of nest that was constructed. Lee and

Wong (1970) also used free access to cotton to measure the nesting behavior of inbred strains of mice.

In all of the experiments cited above, data were collected under conditions where the nesting materials were presented on a free access or continuous reinforcement basis. Many other schedules of presentation of nesting material are conceivable, however, and scheduling techniques other than continuous reinforcement can yield data that would not be observed using simple free-access procedures, as was demonstrated above.

Teitelbaum (1966) has made a convincing case that the most fruitful laboratory method available for the behavioral investigation of homeostatic processes such as feeding or thermoregulation is operant conditioning. With the interpolated, arbitrary operant (usually a bar-press) used in conjunction with the electromechanical programming and recording equipment, an experimenter can program a complicated series of environmental events (schedules of reinforcement) and then, on an on line cumulative recorder, can see the moment-to-moment effects of the various schedules on an animal's operant behavior. The effects of experimental manipulations can then be assessed using the same scheduling and recording procedures just outlined to provide a pre-manipulation experimental baseline.

Two recent studies have demonstrated the practicality of employing operant techniques in the study of mammalian nesting behavior. Jansen, Goodman, Jowaisas, and Bunnell (1969) have shown that hamsters will learn an arbitrary operant response when the presentation of nesting material (paper strips) is the response-contingent event. More recently, Oley and Slotnick (1970) have provided a systematic replication of the Jansen et al. (1969) study, using pregnant and maternal laboratory rats as subjects. At one time, all laboratory rats would readily build nests at relatively low ambient temperatures (Kinder, 1927), but the fact that the nest-building "instinct" has not been selected for in the last two hundred or so generations of laboratory rats has allowed this behavior pattern to deteriorate to the point where laboratory rats now make especially poor subjects for nest-building experiments. The hamsters that were used in the experiments to follow have been in the laboratory for a shorter time than rats, and nesting behaviors are still firmly established in their response repertoire.

Overview and Objectives

In the present series of experiments, the instinctive nesting behavior of the golden hamster was broken into two components, (a) the gathering of nesting material and (b) the actual nest building itself. The first component of this instinctive chain, the acquisition of nesting material, was subjected to an operant analysis, using schedules of reinforcement as an analytic tool. In addition to studies of nesting behavior, data will also be presented on the food-reinforced operant behavior of hamsters. Food-reinforced behavior can serve as a convenient point of comparison to assess schedule effects of other reinforcers such as nesting material, since a vast body of experimental literature on food-maintained operant behavior is available (Honig, 1966).

The experiments to be described below have used operant techniques to probe the nesting behavior of the hamster, since operant conditioning procedures have previously been very productive in the study of homeostatic behavioral processes such as those described in great detail by Teitelbaum (1966). The specific findings that will be presented include:

1) The effects of some basic schedules of paper reinforcement, including fixed-ratio, fixed-interval, variable-interval and differential reinforcement of low rate schedules.

2) Fixed-ratio and variable-interval schedules of food reinforcement in both food-deprived and non-food-deprived animals.

3) The effects of multiple schedules of food and paper reinforcement including multiple fixed-ratio--fixed-ratio and multiple variable-interval--variable-interval schedules.

4) Progressive-ratio schedules of food and paper reinforcement.

METHOD

Subjects

The subjects in the present series of experiments were 13 adult golden hamsters (Mesocricetus auratus). These animals, 4 males and 9 females, were purchased from the Manor Farms, Staatsburg, New York, and were approximately 120-150 days old when testing began. They were individually housed throughout testing in modified standard rat cages (Wahmann Mfg. Co.) with removable fronts. Laboratory chow and water were continuously available when the home cage was in the colony room holding rack, but were unavailable during experimental sessions.

Apparatus

Colony room temperature was maintained at 66° F. (±3°). A 12-12 light-dark cycle was maintained in the room, with the lights off from 8 a.m. to 8 p.m. All experimental sessions were conducted during the dark phase of the light cycle.

Two versions of the same basic paper delivery apparatus were used in these experiments. The first apparatus (Type I) was an earlier model that had several weaknesses which were eliminated in the second apparatus (Type II). Most of the data that will be presented below were collected using the second apparatus (Type II), but some data collected with the older apparatus will be included, as they allow interesting comparisons to be made.

Type I Apparatus

The Type I apparatus consisted of a motor-driven paper dispenser and small bar mounted on a Plexiglas panel 18 cm. by 18 cm. The panel could be fitted on the front of a hamster's home cage in place of the normal wire mesh covering. All animals were tested in their home cages with this apparatus. The sounds of the paper dispenser motor and the dim flash of a neon bulb accompanied paper delivery.

A major difficulty that developed using this apparatus was that during testing it was impossible to isolate the animal working for paper from the rest of the hamster colony, or from the programming and recording equipment. It was observed that testing the hamsters in their home cages was advantageous in that it eliminated much exploration and scent marking. Therefore, the home cage feature of the earlier testing situation was carried over and incorporated into the experiments using the Type II apparatus.

Type II Apparatus

The paper delivery device used for most of the data collection in the present study is shown in Figure 1. The drive (a) and idler (b) rollers were made of aluminum rod, 2.54 cm. in diameter and 1.27 cm. wide, and were center drilled to fit the motor shaft. A medium knurl was machined on the roller surfaces. A set screw locked the drive roller to the motor shaft, and the idler roller ran freely on its shaft (c). The idler roller assembly was held between the side plates (d) which are mounted on the motor housing (e). Tension for the idler roller was provided by one or two large rubber bands (not shown) looped around the extended ends of the idler shaft and over the top of the side plates. The paper drive motor was a 30 RPM

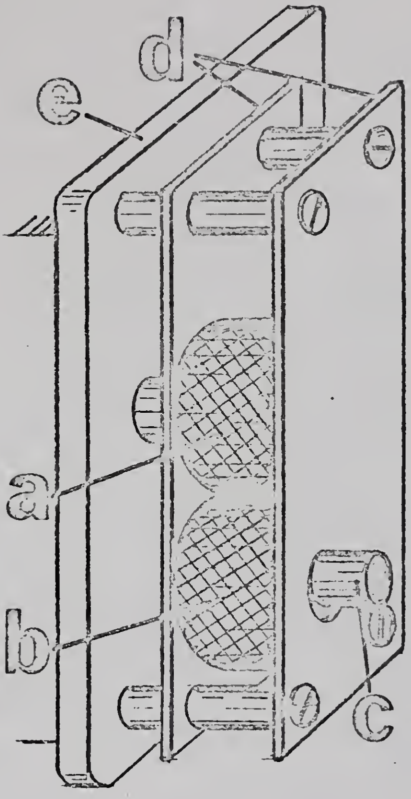

Figure 1: Paper delivery apparatus, including the drive (a) and idler (b) rollers, roller shaft (c), side plates (d) and motor housing (e).

shaded pole AC motor that has delivered more than 10,000 paper strips without malfunction.

The delivery mechanism was mounted against the rear of the stimulus panel that forms the front of the experimental chamber. The 3 cm. strip of 1.03 cm. wide teletype paper that served as the response-contingent event (reinforcement) was delivered through a hole in the panel. The experimental chamber consisted of the subject's home cage with a Plexiglas top fitted over it. The home cage was a Wahmann rat cage with the front cut out and replaced by a removable .63 cm. mesh hardware cloth front that was held in place by a spring during non-experimental periods. During experimental sessions the front of the cage was removed and the cage was locked in place against the stimulus panel. With the Plexiglas top in place the working space was 27 cm. high, 18 cm. wide, and 25 cm. long. The cage floor was divided into front and rear halves by a 2.5 cm. high angle iron, and the rear half of the floor was covered with .63 cm. mesh hardware cloth while the front half had the standard 1.27 cm. mesh floor. This arrangement was dictated by the behavioral patterns of the hamsters. When a strip is delivered, the hamster quickly chews it off against the tension of the rollers and stores the strip in its cheek pouches. When the pouches are distended (about 250 cm. of paper) the hamster stops key pressing and unpouches the nest material in its preferred nest site, usually a corner of the cage. Since the paper strips fall through the 1.27 cm. mesh floor in the front of the cage into the droppings pan below, the divided floor arrangement encouraged unpouching in the rear of the cage where the nest was less likely to provide stimuli for behaviors that were incompatible with continued responding on the key.

The manipulandum was a Gerbrand's "Harvard Pigeon Key, Model A", mounted 4.5 cm. to the right of the paper delivery hole and 9 cm. above the cage floor. A force of 15 grams opened the contacts of the key and activated a response feedback relay located behind the stimulus panel. A second key was located 5 cm. to the right of the first key. This second key and its associated food chute were covered during sessions when food delivery was not programmed. When food delivery was programmed, food reinforcement consisted of a single 45 mg. Noyes food pellet.

The stimulus panel and paper delivery apparatus were housed in a sound-attenuated enclosure ventilated by an exhaust blower. Responses were recorded on electromechanical counters and cumulative recorders. All programming and recording equipment was located in an adjacent room.

Procedure

The hamsters were first allowed several days of adaptation to the home cages before any experimental procedures were begun. During this time all hamsters were tested for their ability to rapidly cut off short strips of the ticker tape paper that were inserted into their cages through the wire fronts. Previous experiments had shown that an occasional hamster could not cut off the paper strips.

Experimental sessions were held daily, and each session began with 10 minutes of adaption in the enclosure. During adaptation the response key was dark and a red house light, mounted in the top of the Plexiglas cage cover, was illuminated. The start of a session was signalled by the offset of the house light and the onset of an AC white light transilluminating the response key. At the end of a session, the keylight went off and the house light was again illuminated. Sessions lasted from 30 to 350 minutes depending on the schedule in effect. More than 125 paper strips were typically delivered in a session, enough material to provide a large, cup-shaped nest.

Subjects were deprived of most of their previous day's accumulation of paper 6 to 8 hours prior to a session. A small amount of paper, sufficient for making a pallet, was left in the cage, since past experience has shown that if all paper was removed, the first unpouching episode of the session was often followed by very long pauses rather than an immediate return to the key. Visual observation of the animals during these pauses showed that the hamsters typically engaged in grooming and nest building after unpouching the accumulated paper. Leaving a small amount of paper from the previous session decreased these episodes of behavior that were incompatible with key responding.

One or two 30-minute sessions of free operant levels of key pressing were obtained before magazine training was begun. The only programmed consequence of the key presses during these sessions was the operation of the feedback relay. Standard magazine training and shaping procedures (Skinner, 1938) were used in subsequent sessions until the hamsters were responding reliably on a fixed-ratio of one response (FR 1). A tone of one-second duration, 2.5 KHz, and approximately 72 db. accompanied paper delivery. When food sessions were programmed, or when food was presented during a multiple schedule, a 4.5 KHz tone of one-second duration accompanied food delivery. Schedule requirements were gradually raised after initial training until the hamsters were responding on the terminal values of the schedules imposed. A complete summary of each hamster's experimental history is provided in Tables 1-a to 1-f.

The reinforcement schedules that were programmed included the following:

A. Fixed-Ratio (FR). Each reinforcement is scheduled following a predetermined, fixed number of responses.

B. Fixed-Interval (FI). Each reinforcement is scheduled following the first response after a fixed period of time has elapsed.

C. Variable-Interval (VI). Each reinforcement follows the first response after a variable period of time has elapsed. The schedule is identified in terms of the average interval between reinforcements.

D. Differential Reinforcement of Low Rates (DRL). A response is reinforced only if at least a specific period of time has elapsed since the last response.

E. Progressive-Ratio (PrRn). Each reinforcement follows a progressively increasing number of responses. Thus the first reinforcement might require 5 responses, the second 10, the third 15, and so on. This would be a "progressive ratio-5" (PrR5) schedule, since each reinforcement requires 5 more responses than the one that precedes it.

F. Multiple Schedules (MULT). Two (or more) schedules are programmed to operate alternately, each in the presence of a different stimulus. In the multiple schedules programmed in the present study, components were changed at regular intervals so that the food and paper schedules and their respective response keys and reinforcement dispensers were operative alternately.

Other added contingencies were sometimes programmed in conjunction with these schedules, and such additions will be so noted in the Results section. These added contingencies were:

a. Limited Hold (LH). This contingency signifies the termination of the scheduled availability of the reinforcement if the response to be reinforced does not occur within a specified period of time.

b. Time Out (TO). This contingency means that at certain signalled times responses on the operant manipulandum have no programmed consequences. TOs are programmed at the beginning and end of an experimental session, and between components of a multiple schedule.

c. Change-Over Delay (COD). This contingency is added to multiple schedules to insure that there is no superstitious conditioning when an animal is changing from one response key to the other. If a response is made during the COD, the onset of the next component of the schedule is delayed for a fixed period of time.

TABLE 1-a

Sequence of Experimental Manipulations and Number
of Sessions for Each Procedure

Hamster AW-1

Procedure		Sessions
FR 1	Paper	3
FR 4	Paper	2
FR 6	Paper	2
FR 8	Paper	2
FR 10	Paper	1
FR 12	Paper	1
FR 20	Paper	3
FR 25	Paper	4
FR 25	Food	5
FR 25	Paper	7
MULT 25 - FR 25		10
Alternating Daily		
PrR5	Paper First	8
PrR5	Food	8

Hamster AW-2

Procedure		Sessions
FR 1	Paper	4
FR 5	Paper	1
FR 10	Paper	3
FR 15	Paper	6
FR 20	Paper	4
FR 10	Paper	2
FR 12	Paper	1
FR 15	Paper	1
FR 20	Paper	3
FR 25	Paper	1
FR 20	Paper	7
FR 25	Paper	8
FR 5	Food	1
FR 10	Food	2
FR 20	Food	1
FR 25	Food	1
FR 25	Paper	4.
MULT FR 25 - FR 25		10
Alternating Daily		
PrR5	Food First	8
PrR5	Paper	8

TABLE 1-b

Sequence of Experimental Manipulations and Number of Sessions for Each Procedure

Hamster AW-3

Procedure	Sessions
FR 1 Paper	4
FR 5 Paper	1
FR 10 Paper	3
FR 15 Paper	6
FR 20 Paper	4
FR 10 Paper	1
FR 12 Paper	1
FR 15 Paper	1
FR 20 Paper	4
FR 25 Paper	4
FR 5 Food	1
FR 25 Paper	3
FR 15 Food	2
FR 20 Food	2
FR 25 Food	4
MULT FR 25 - FR 25	10
Alternating Daily	
PrR5 Food First	8
PrR5 Paper	8

Hamster AW-4

Procedure	Sessions
FR 1 Paper	4
FR 5 Paper	1
FR 7 Paper	1
FR 10 Paper	3
FR 15 Paper	5
FR 20 Paper	4
FR 10 Paper	2
FR 15 Paper	1
FR 20 Paper	4
FR 25 Paper	7
FR 2 Food	1
FR 5 Food	1
FR 10 Food	1
FR 12 Food	1
FR 15 Food	1
FR 25 Paper	1
FR 15 Paper	4
MULT FR 25 - FR 25	10
Alternating Daily	
PrR5 Paper First	8
PrR5 Food	8

TABLE 1-c

Sequence of Experimental Manipulations and Number of Sessions for Each Procedure

Hamster AW-5

Procedure	Sessions
FR 1 Paper	3
FR 4 Paper	2
FR 6 Paper	2
FR 8 Paper	2
FR 10 Paper	1
FR 12 Paper	1
FR 15 Paper	1
FR 20 Paper	12
FR 25 Paper	8
FR 5 Food	1
FR 8 Food	1
FR 10 Food	1
FR 12 Food	1
FR 15 Food	1
FR 25 Paper	1
FR 15 Paper	1
MULT FR 25 - FR 25	10
Alternating Daily	
PrR5 Food First	8
PrR5 Paper	8

Hamster EF-23

Procedure	Sessions
FR 1 Paper	2
FR 3 Paper	1
FR 5 Paper	1
FR 8 Paper	1
FR 10 Paper	1
FR 12 Paper	1
FR 15 Paper	19
EXTINCTION	3
FR 10 Paper	1
FR 15 Paper	1
FR 18 Paper	2
FR 20 Paper	1
FR 22 Paper	1
FR 25 Paper	31
FR 20 Paper	2
FR 10 Paper	61

TABLE 1-d

Sequence of Experimental Manipulations and Number of Sessions for Each Procedure

Hamster M-10

Procedure	Sessions
FR 1 Paper	4
FR 10 Paper	1
FR 15 Paper	1
FR 10 Paper	5
FR 20 Paper	1
FR 25 Paper	4
FR 30 Paper	2
FR 35 Paper	1
FR 40 Paper	2
FR 45 Paper	7
FR 50 Paper	4
FR 60 Paper	4
FR 75 Paper	3
FR 85 Paper	2
FR 80 Paper	2
FR 100 Paper	5
FR 125 Paper	1
FR 150 Paper	1

Hamster F-1

Procedure	Sessions
FR 1 Paper	6
VI 10 sec. Paper	5
VI 15 sec. Paper	2
VI 10 sec. Paper	3
VI 20 sec. Paper	4
VI 10 sec. Paper	3
VI 20 sec. Paper	1
VI 30 sec. Paper	3
FR 10 Paper	2
FR 15 Paper	2
FR 20 Paper	1
FR 25 Paper	1
FR 30 Paper	2
FR 35 Paper	4
FR 30 Paper	2
FR 35 Paper	2
FR 40 Paper	3
FR 45 Paper	7
EXTINCTION	14

TABLE 1-e

Sequence of Experimental Manipulations and Number of Sessions for Each Procedure

Hamster F-5

Procedure		Sessions
FR 1	Paper	2
VI 5 sec.	Paper	2
VI 10 sec.	Paper	3
VI 20 sec.	Paper	4
VI 15 sec.	Paper	2
VI 20 sec.	Paper	3
VI 30 sec.	Paper	13
VI 45 sec.	Paper	20
EXTINCTION		7

Hamster M-20

Procedure		Sessions
FR 1	Paper	3
FR 5	Paper	2
FI 10 sec.	Paper	5
FI 30 sec.	Paper	3
FI 1 min.	Paper	4
FI 2 min.	Paper	5
FI 3 min.	Paper	24
FI 4 min.	Paper	10

TABLE 1-f

Sequence of Experimental Manipulations and Number of Sessions for Each Procedure

Hamster M-11

Procedure			Sessions
FR	1	Paper	2
FR	5	Paper	1
FR	10	Paper	2
FR	12	Paper	2
DRL	15 sec.	Paper	9
DRL	20 sec.	Paper	4
DRL	30 sec.	Paper	3

Hamster FM-1

Procedure			Sessions
FR	1	Paper	3
FR	2	Paper	4
VI	10 sec.	Paper	15
VI	16 sec.	Paper	17
VI	30 sec.	Paper	72
VI	30 sec.	Food	35
MULT VI 30 sec. - VI 30 sec.			10

Hamster HF-5

Procedure			Sessions
FR	1	Paper	1
FR	5	Paper	2
VI	10 sec.	Paper	5
VI	16 sec.	Paper	4
VI	23 sec.	Paper	2
VI	35 sec.	Paper	2
VI	45 sec.	Paper	14

RESULTS

Free operant rates were low, ranging from 2 to 25 responses per half hour. Magazine training and shaping was complete within two to three sessions.

Figure 2 shows representative cumulative records from three female subjects, EF-23, AW-3 and AW-4 under fixed-ratio schedules of paper delivery. Key responses step the event pen vertically from the baseline, and diagonal hatch marks indicate the delivery of a strip of paper. The characteristic fixed-ratio pattern of responding is apparent in these records, with bursts of responding alternating with post-reinforcement pauses (Ferster & Skinner, 1957). Record A for hamster EF-23 was made on the 16th session of responding on a fixed-ratio 25 schedule, while Record B was made on the 27th session.

Long pauses such as those in Record B appeared in some cumulative records, but were absent in the majority of sessions. When pauses did occur they usually were seen only after 60 to 80 strips of paper had been accumulated and a recognizable nest had begun to take shape in the animal's cage. Visual monitoring of the hamsters during experimental sessions indicated that the pauses in responding were correlated with the unpouching of paper and nest-directed activities such as paper chewing. Before returning to key pressing, the nest-directed behaviors were often followed by a period of

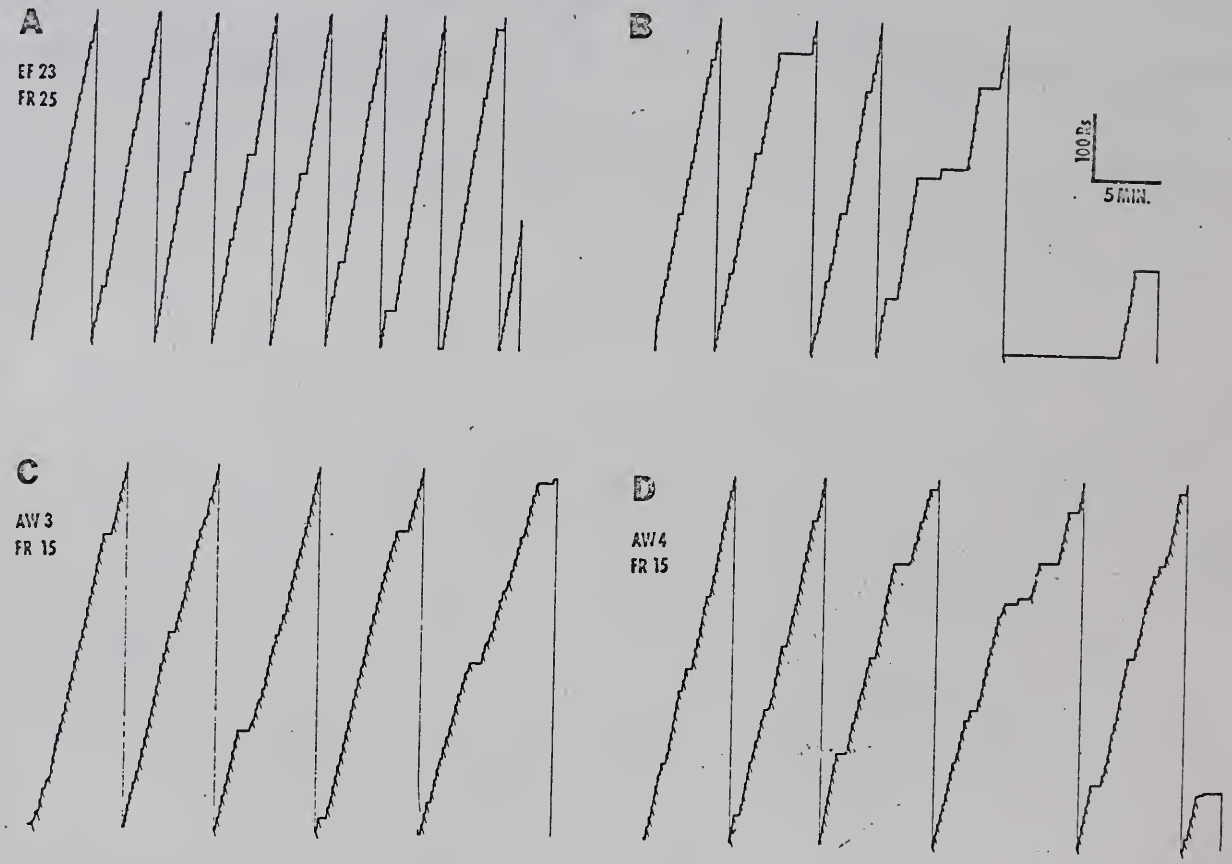

Figure 2: Representative cumulative records from female hamsters EF-23, AW-3 and AW-4 under fixed-ratio schedules of paper delivery.

repetitive rearing against the walls of the cage, and scratching them with the forepaws. This stereotypic pattern of rearing and scratching is a high probability behavior that is observed in hamsters during open field tests (Jowaisas, 1969).

The bottom two records in Figure 2 show representative cumulative records from two other female hamsters, AW-3 and AW-4. Record C shows AW-3's typical performance on the fourth session of an FR 15 schedule of paper delivery, while Record D shows AW-4's performance on the third session of an FR 15 schedule. In these records, pauses from key pressing were typically correlated with the collateral behaviors described for EF-23.

Figure 3 shows representative cumulative records from two more hamsters, a male and a female, on fixed-ratio schedules of paper reinforcement. These records were collected using the older, Type I apparatus described above. The records in Figure 3 have been collapsed in the manner of Ferster and Skinner (1957) to give a better visual representation of any successive changes in response rates (slope) over time. The record for M-10, the male, was made on the 4th session of responding on a fixed-ratio schedule of 60 responses, and the record for F-1, the female, was made on the 4th session of responding on a fixed-ratio schedule of 45 responses. The pattern of responding characteristic of fixed-ratio schedules of reinforcement is apparent in these records (Ferster and Skinner, 1957). Both hamsters were brought gradually to these higher schedule values, with response requirements being raised in increments of 5 or 10 responses when behavior had stabilized at a lower level.

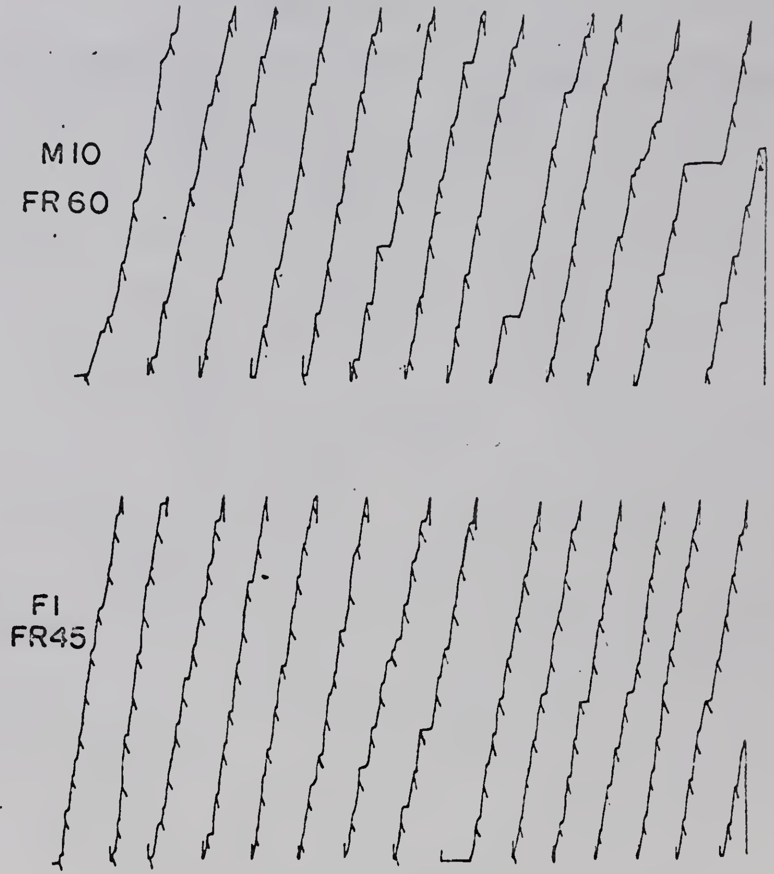

Figure 3: Representative cumulative records for male hamster M-10 and female hamster F-1 under fixed-ratio schedules of paper delivery.

Figure 4 shows three consecutive sessions of female EF-23's responding on a fixed-ratio 15 schedule of paper reinforcement (bottom collapsed records), and three sessions of extinction that followed (top records). The fixed-ratio records were from the 17th, 18th, and 19th sessions of responding on the FR 15 schedule, and the extinction records were made on the next three sessions. These records were all collected using the Type I apparatus. In the extinction sessions the flashing neon bulb and the paper dispenser motor still operated on an FR 15 (diagonal hatch marks), but no paper was delivered. These records demonstrate typical responding on a fixed-ratio schedule, followed by typical extinction after FR responding, with post-reinforcement pauses gradually becoming longer, and responding occurring less frequently. When responding did occur, however, the bursts of responses characteristic of fixed-ratio schedules still appeared.

Figure 5 shows two representative cumulative records of hamster F-5, a female, responding on a variable-interval 45 seconds (VI 45") schedule of paper delivery. The record marked "OLD" was made on the 9th session in the older, Type I apparatus, while the "NEW" record was made on the 7th session in the more recent Type II apparatus described above. From the slopes of the collapsed records it can be seen that the rate of responding in the older apparatus stayed constant throughout the session, while the rate was decelerating over time in the newer apparatus.

Figure 6 shows a representative cumulative record for hamster M-20, a male, responding on the 7th session of a fixed-interval

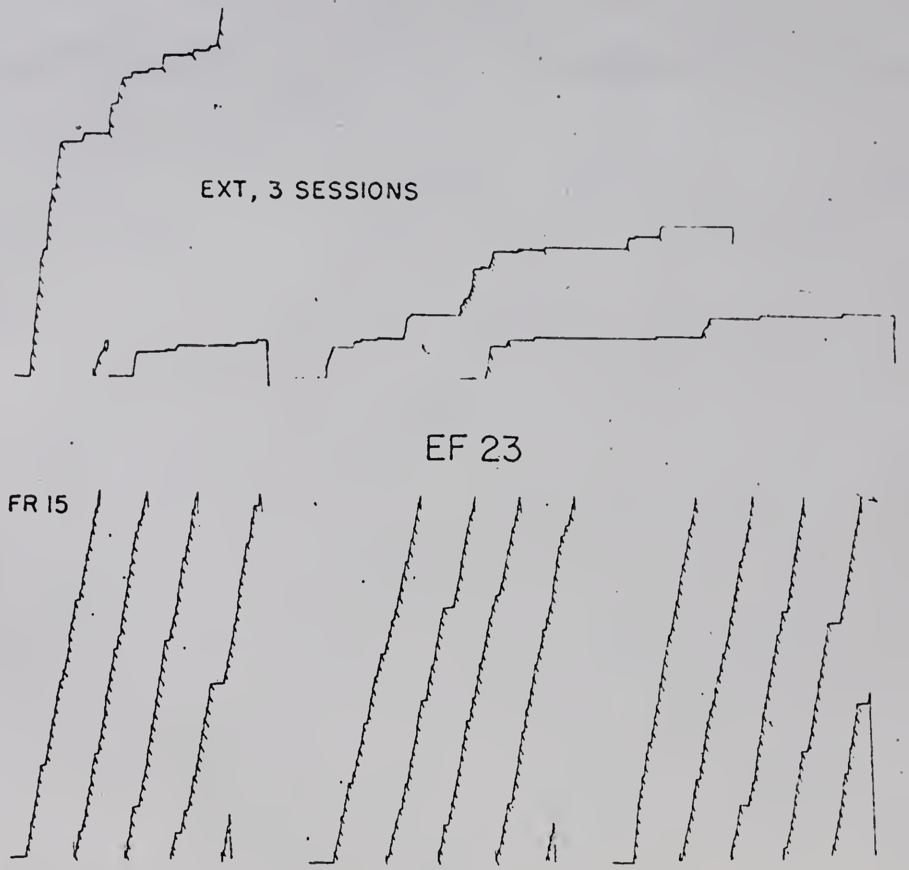

Figure 4: Representative cumulative records for female hamster EF-23 under fixed-ratio schedules of paper reinforcement (bottom records) and extinction (top records).

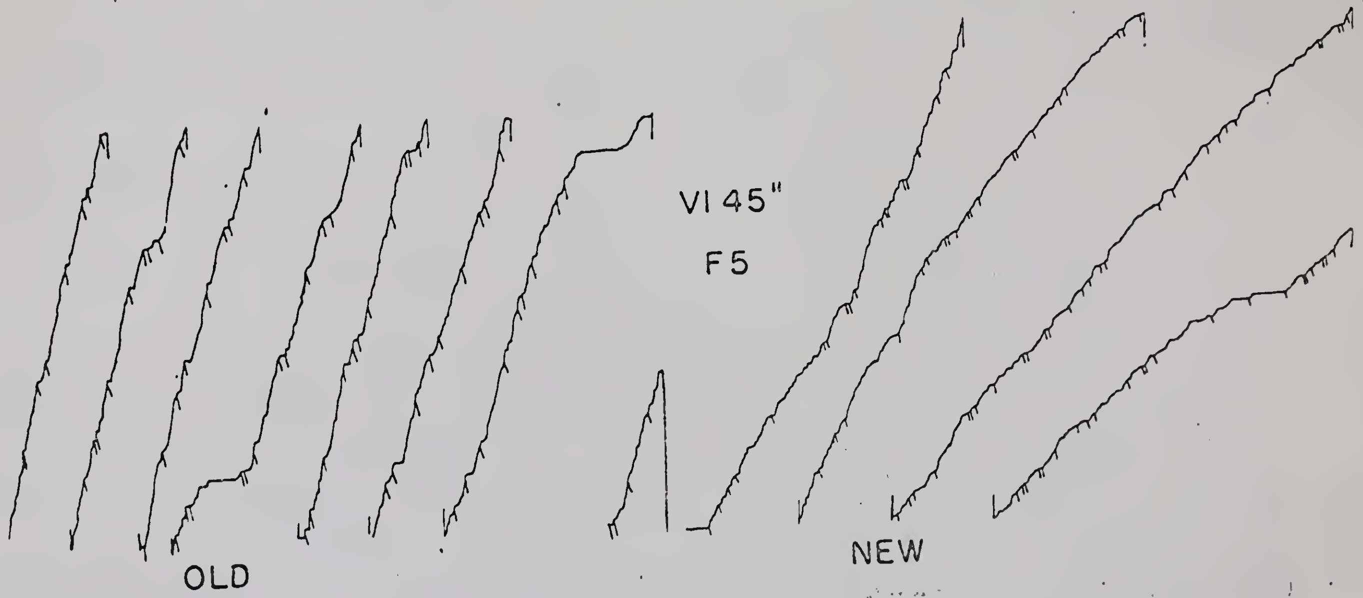

Figure 5: Representative cumulative records of female hamster F-5 under a variable-interval 45 seconds schedule of paper delivery in the old and new versions of the apparatus.

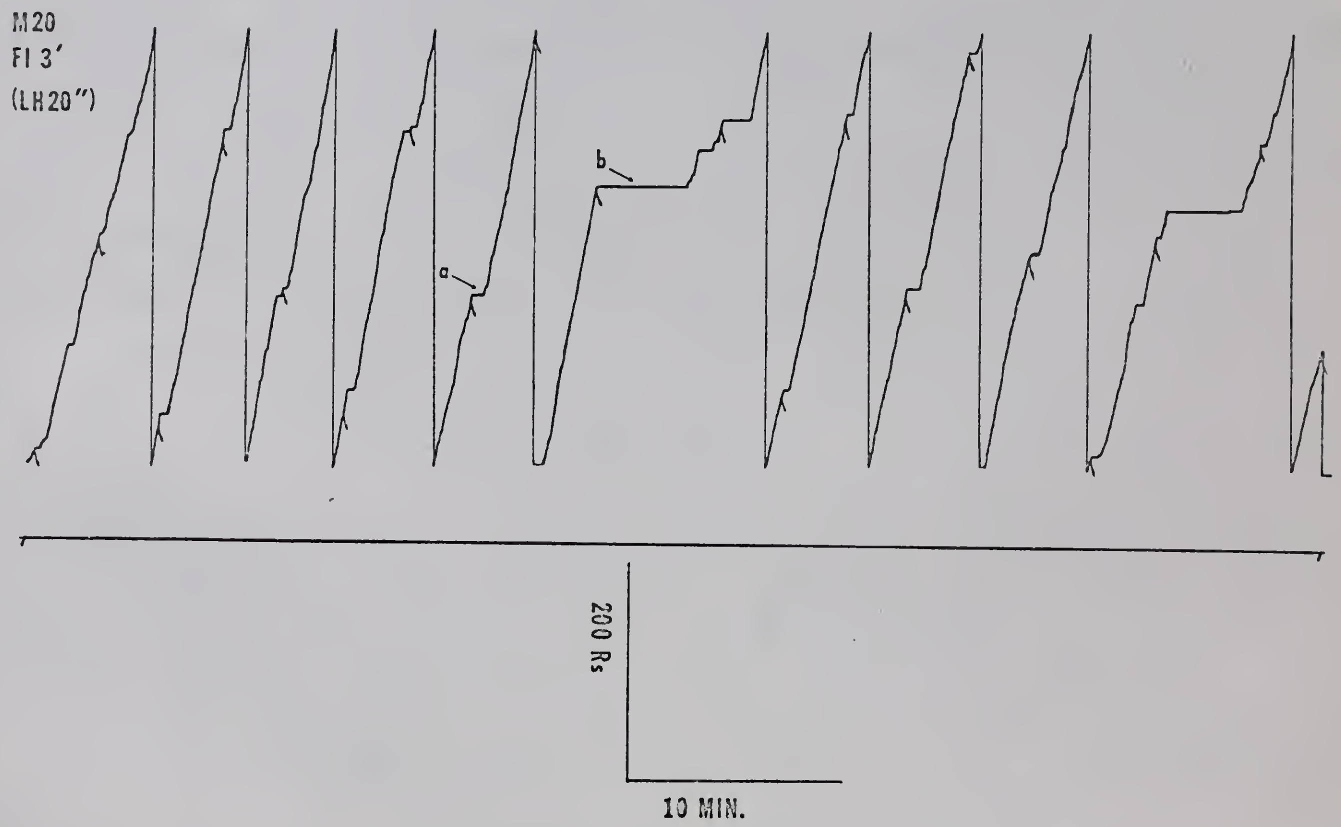

Figure 6: Representative cumulative record of male hamster M-20 under a fixed-interval 3 minutes schedule of paper reinforcement.

3 minutes (FI 3') schedule of paper delivery. This record was made using the Type I apparatus. A limited hold (LH) contingency of 20 seconds was programmed into this schedule, so that if no responses occurred within 20 seconds after a reinforcement was made available, the schedule was recycled and another 3-minute interval had to elapse before a strip of paper was again available. Although the classical, positively accelerated fixed-interval pattern of responding (Ferster & Skinner, 1957) was never replicated in this animal in over 50 sessions of fixed-interval responding, the post-reinforcement pause characteristic of fixed-interval did sometimes occur, for example at point (a). Once this hamster began pressing the bar, however, it responded at a high and fairly constant rate throughout the whole of the fixed-interval period. Point (b) shows one of the places in this animal's responding where the limited hold contingency caused the hamster to miss a programmed reinforcement. In general, then, this animal's fixed-interval performance was never strongly under the control of the prevailing schedule as the responding of animals of FR and VI schedules had been.

Figure 7 shows a representative cumulative record of hamster M-11, a male, responding on a differential reinforcement of low rate (DRL) 20 seconds schedule of paper delivery. This record was made on the 4th session of DRL 20" responding, using the Type I apparatus. Under this schedule, there must be a pause of at least 20 seconds before a response produces a strip of paper. Figure 7 demonstrates good DRL performance maintained by paper, with responses well spaced and no long bursts of responding evident.

Figure 8 shows two cumulative records from hamster AW-1, a female, responding on the first (bottom) and second (top) sessions

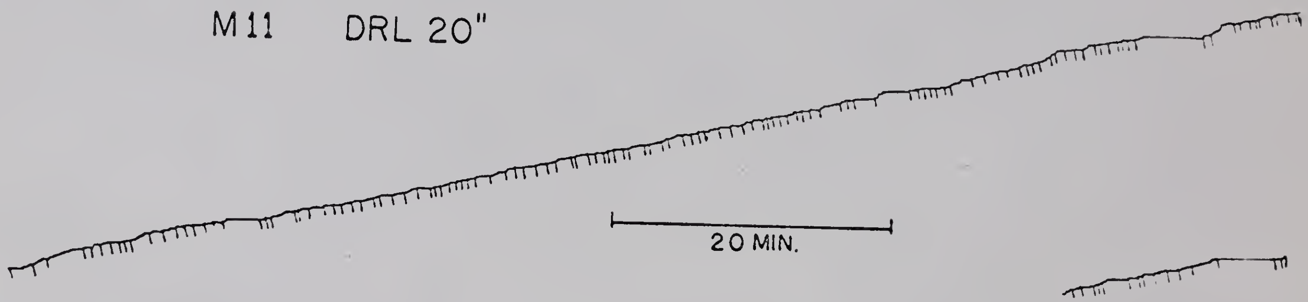

Figure 7: Representative cumulative record of male hamster M-11 under a DRL schedule of paper delivery.

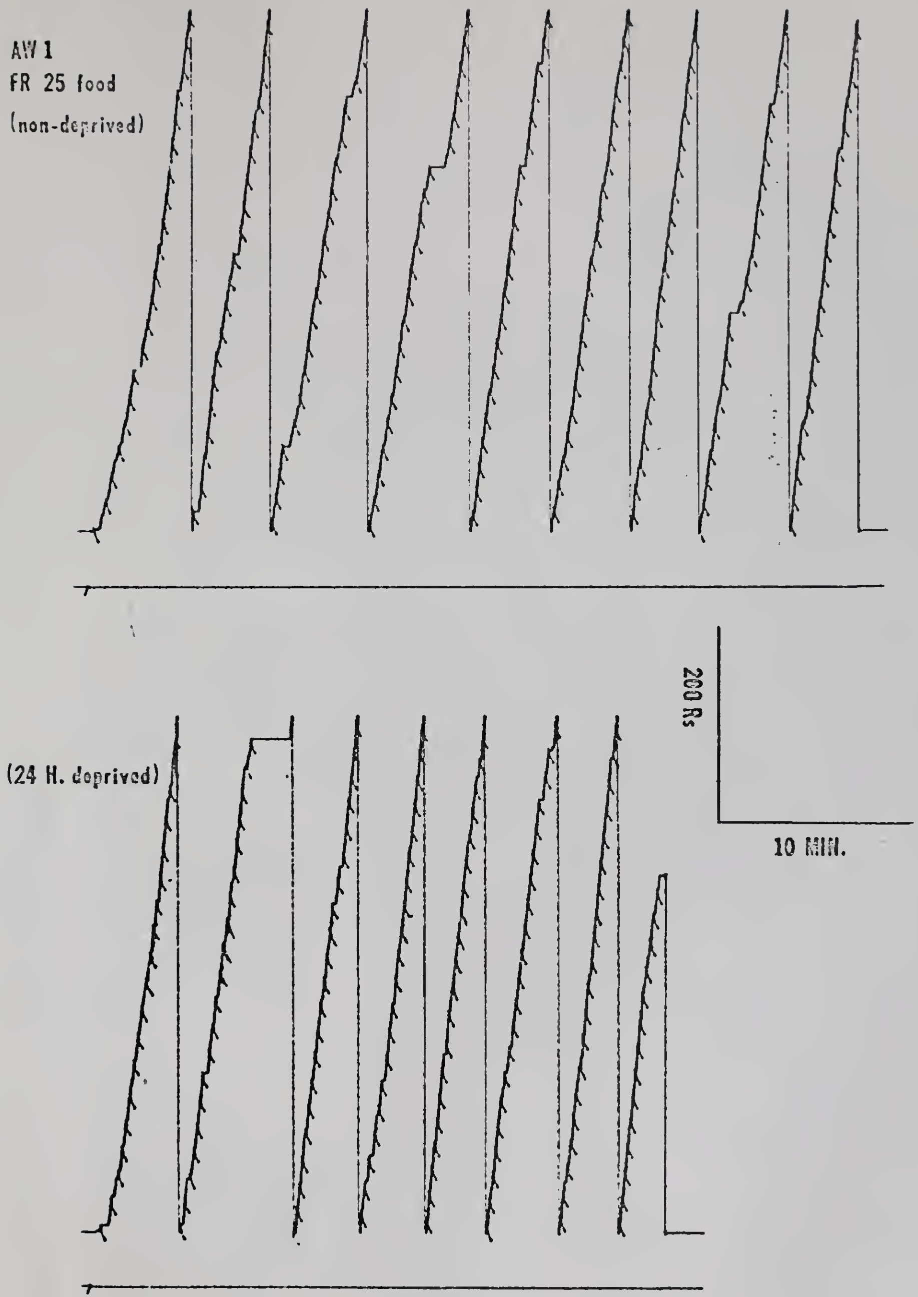

Figure 8: Representative cumulative records of female hamster AW-1 under a fixed-ratio schedule of food reinforcement. The hamster was not food-deprived in the top record, and was 24-hours food-deprived in the bottom record.

of a fixed-ratio 25 schedule of food presentation. The diagonal hatch marks indicate the delivery of a 45 mg. Noyes food pellet. As was noted above, food-maintained operant behavior was studied in the present series of experiments as a point of comparison for the paper-maintained responding. Most studies of food-maintained operant behavior use animals that have been reduced to 90% or 80% of their free-feed weight at the time of testing. Since hamsters hoard food above and beyond their immediate requirements, it was hypothesized that severe food deprivation would be unnecessary in order to study the hamster's food-maintained behavior.

Both records in Figure 8 were collected using the Type II apparatus. In the top record, the hamster was not deprived of food before the session began, and three large pellets of Purina Lab Chow were left in the cage throughout the session. In the bottom record, the same hamster was deprived of all food 24 hours before the session began. In both records, it is quite apparent that good FR performance was being maintained, and that the deprivation condition had no noticeable effect on responding. Figure 9 shows hamster AW-1's response rate on four consecutive food-maintained sessions. This Figure, like Figure 8, shows that food deprivation had no apparent effect on FR response rates. In summary, both food (Figure 8) and paper (Figure 2) maintain comparable rates of fixed-ratio responding in the hamster, and food deprivation proved to be an unnecessary condition for conducting food-maintained operant research.

Figure 10 shows representative cumulative records from two more hamsters, FM-1 and HF-5. FM-1, a male, was maintained at approximately 80% of free-feeding body weight, and was trained under a

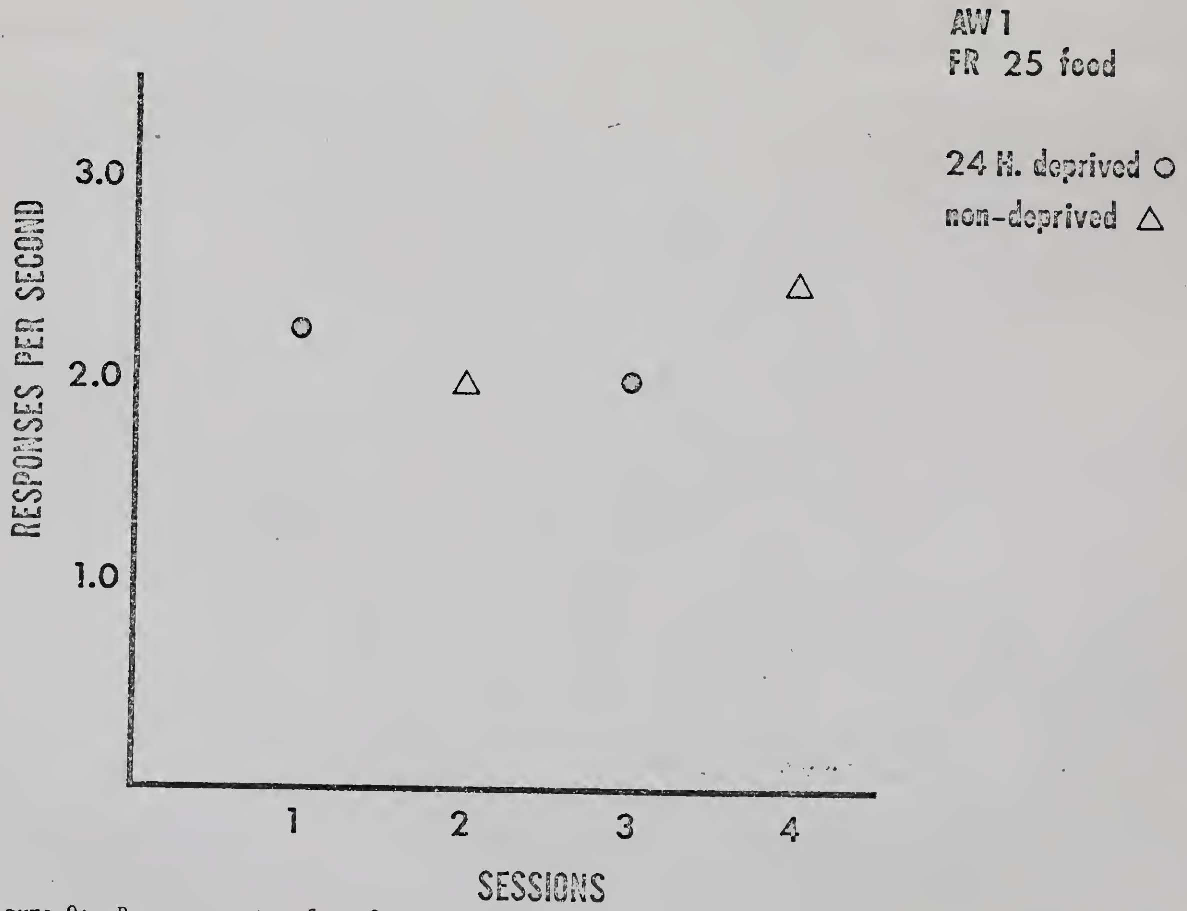

Figure 9: Response rates from four consecutive sessions of female AW-1 under a fixed-ratio 25 schedule of food reinforcement. In the first and third sessions the hamster was food-deprived for 24 hours before responding, and in the second and fourth sessions the hamster was not deprived

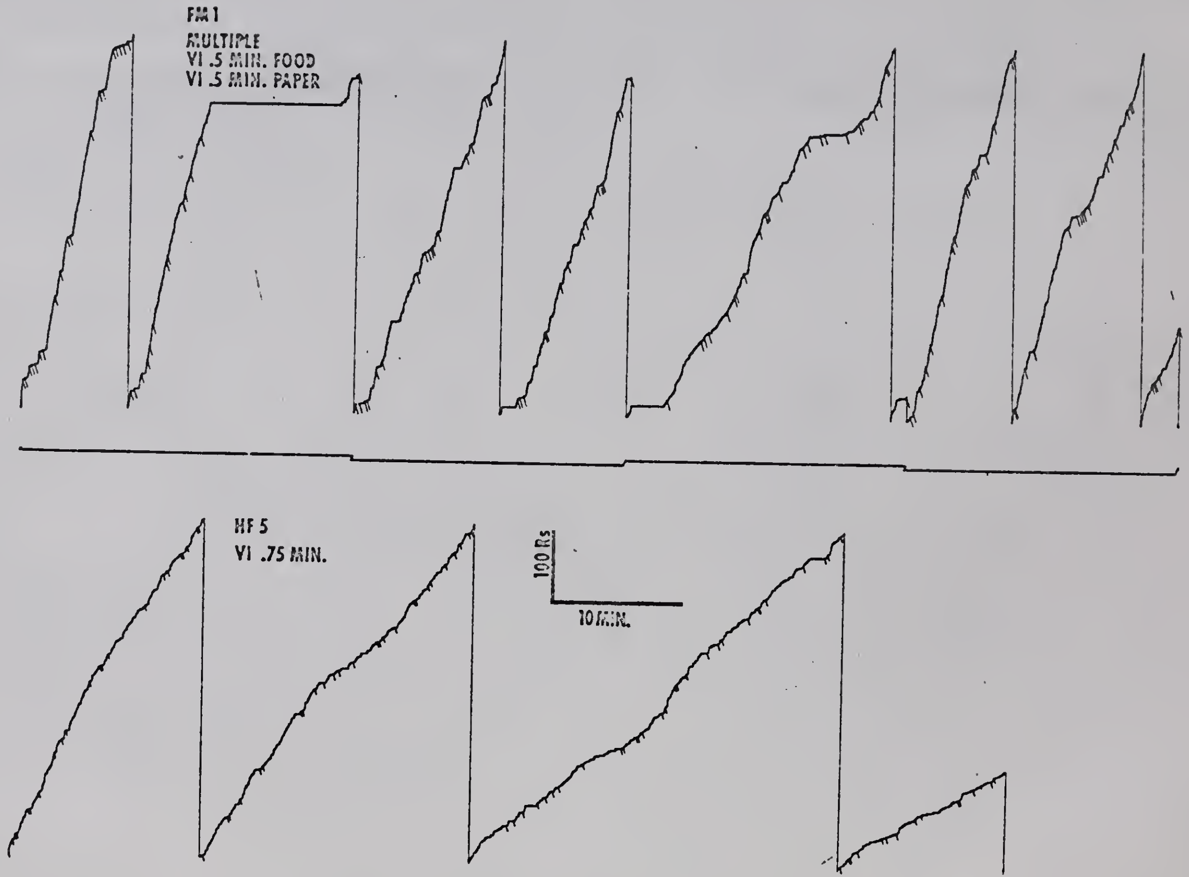

Figure 10: Representative cumulative records of male hamster FM-1 under a multiple variable-interval schedule of food and paper reinforcement (top record) and of female hamster HF-5 under a variable-interval schedule of paper reinforcement.

multiple variable-interval 30 seconds schedule of both food and paper delivery. The food and paper components of the schedule alternated after the first reinforcement that was delivered after 20 minutes had passed since the initiation of a particular component. The hatch marks indicated delivery of a 45 mg. Noyes food pellet during the food components, and of a 2 cm. strip of teletype paper during paper components. Downward deflections of the baseline event pen indicate paper components, while the food components correspond to the upward excursions of the event pen. A limited hold of 20 seconds was in effect during both components, and a 50-second time out (TO) was programmed between components. In addition, a change-over delay (COD) of 20 seconds for key responses was programmed during the last 20 seconds of the TO period. This record was made on the 6th session under the multiple variable-interval 30 seconds schedule.

With the exception of the single long pause in the first 20-minute food component, both components of this schedule maintained typical variable-interval patterns of responding. The long pause in the first food component was a regular feature of this animal's performance, and it usually occurred at the point where the hamster stopped eating the pellets as they were delivered, and began storing them in its cheek pouches.

The bottom record in Figure 10 shows representative performance of a female hamster, HF-5, on the 11th session under a variable-interval 45 seconds (VI 45") schedule of paper delivery. No limited hold contingency was in effect during this animal's experimental sessions. The gradual decrease in response rate as the session progressed was a characterisitc feature of this animal's performance.

Figure 11 shows representative cumulative records from two female hamsters, AW-5 and AW-2, under a multiple fixed-ratio 25 schedule of paper and food delivery. The records for both animals were collected on the 8th session of responding under the multiple schedule. Both records were collected using the Type II apparatus, as were the records to follow in Figures 12 and 13. Upward deflections of the baseline event pen indicate paper components, while downward excursions of the pen correspond to the food components. Thus in both of these records paper components were presented first. The paper and food components of the schedule alternated after the first reinforcement that was delivered after 10 minutes had elapsed since the initiation of a particular component. A 20-second COD for key responses was programmed between the components, and the hamsters typically unpouched paper and food during these delay periods.

Both records in Figure 11 show good FR responding under each of the components of the multiple schedule. Response rates tended to be slightly higher during food components, but this was due to at least two extraneous factors. First, it took longer for a hamster to tear off a strip of paper and insert it into its cheek pouches than it did to pick up a food pellet and insert it into the pouches. Second, there were often relatively long pauses at the beginning of the first paper component of a session, for example, at point (a) in AW-2's record. Visual monitoring of the hamsters indicated that they typically chewed on the metal food-delivery chute during the

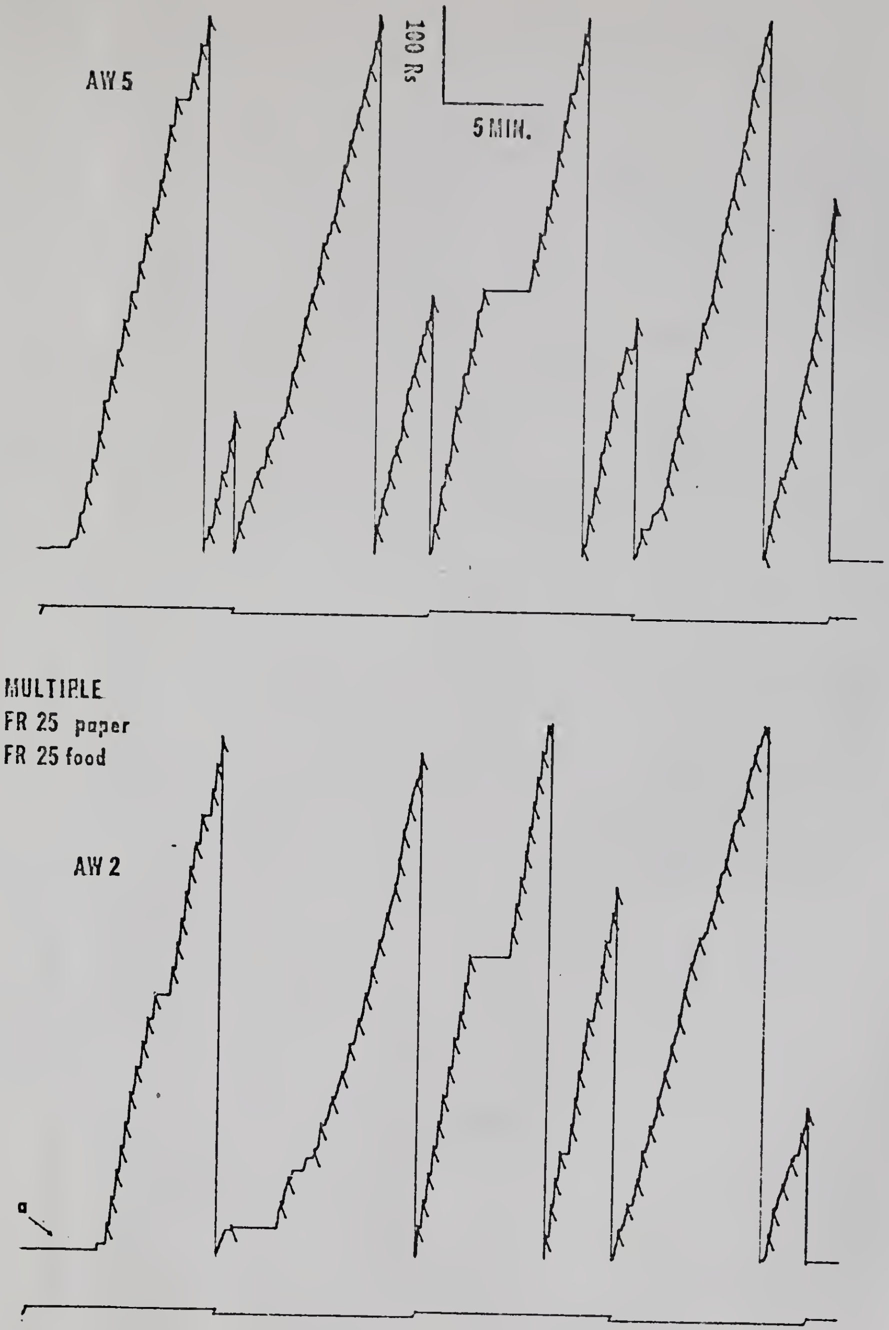

Figure 11: Representative cumulative records of female hamsters AW-5 and AW-2 under a multiple fixed-ratio schedule of food and paper reinforcement.

time out (TO) period preceding the session, and they were often slow in reacting to the paper key light when it first came on.

Figure 12 shows two representative cumulative records for female hamster AW-1 under progressive-ratio 5 (PrR5) schedules of food and paper delivery. The top record shows representative food-maintained performance on the 5th session of responding for food, and the bottom record shows representative paper-maintained responding on the 3rd session of responding for paper. The sessions were automatically terminated when ten minutes had elapsed since the last response was made (Hodos, 1961). Downward deflections of the baseline pen indicate responses on the unlit key during a session. The hamster was not food-deprived during the food-maintained sessions. It is quite apparent from these records that food maintains considerably more progressive-ratio responding than paper in the hamster (also see Table 2), and terminal ratios as high as 250 responses for food were not uncommon in this animal's performance.

Figure 13 shows a representative cumulative record for hamster AW-3, a female, responding under a progressive-ratio 5 schedule of food delivery. This record was made on the 7th session of responding under the PrR5 schedule of food delivery, and was from one continuous session that lasted over three hours. An unusual feature of this animal's performance was that broken and erratic runs of responses occurred periodically during a session (point "a") and visual monitoring indicated that this behavior was correlated with trance-like freezing of the hamster in front of the response key. No "fatigue" explanation can account for this pattern of responding, since later

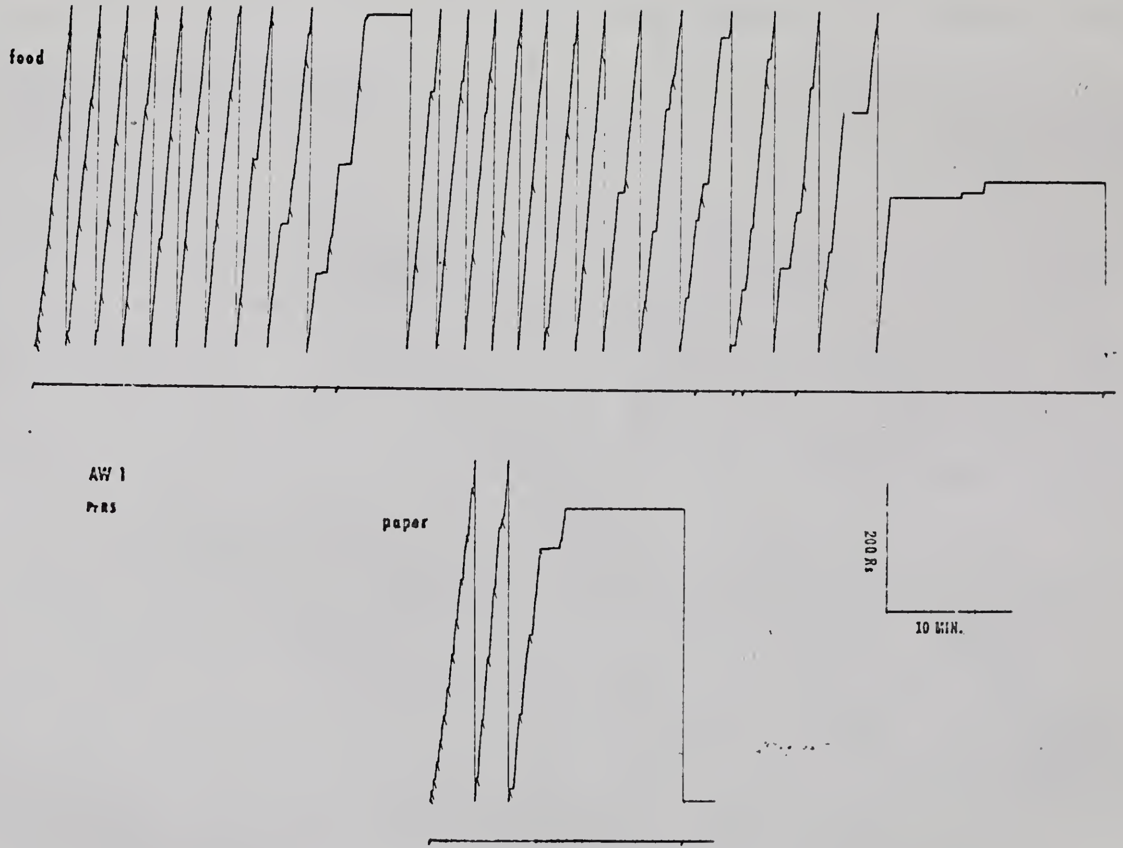

Figure 12: Representative cumulative records of female hamster AW-1 under a progressive-ratio schedule of food (top record) and paper (bottom record) reinforcement.

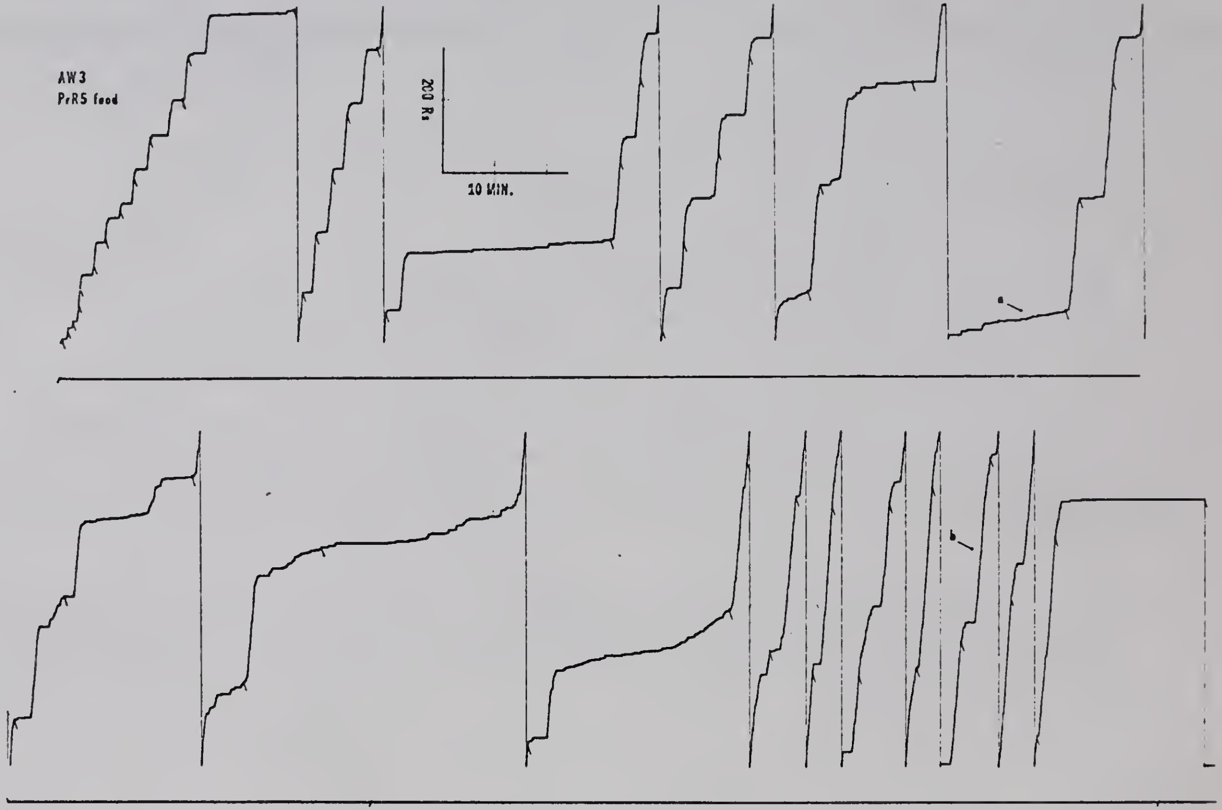

Figure 13: Representative cumulative record of female hamster AW-3 under a progressive-ratio schedule of food delivery.

in the session, for example, at point (b), high, constant rates of responding typically were observed.

Table 2 shows mean and median terminal ratio values for five female hamsters that were used to study progressive-ratio schedules of food and paper delivery. The mean and median values and standard errors were computed for eight sessions of responding for food, and eight sessions of responding for paper. When each animal's food-maintained performance is compared to its paper-maintained performance, it can be seen that food delivery produced higher terminal ratio values than paper. Since progressive-ratio schedules were developed to study motivational aspects of different reinforcers (Hodos, 1961; Keesey & Goldstein, 1968) it can be concluded that food delivery will maintain more behavior in hamsters than paper delivery, even in animals that have never been food-deprived.

TABLE 2

Mean and Median Terminal Values for Five Female Hamsters Under Progressive-Ratio Schedules of Food and Paper Delivery. The Mean and Median Values and Standard Errors Were Computed for Eight Sessions of Responding for Food and Eight Sessions of Responding for Paper.

		HAMSTER				
		AW-1	AW-2	AW-3	AW-4	AW-5
MEDIAN TERMINAL RATIO						
	FOOD	50	29	41	24	43
	PAPER	29	24	19	17	17
MEAN TERMINAL RATIO						
	FOOD	50	24	38	24	43
	PAPER	32	17	18	18	14
STANDARD ERROR						
	FOOD	3.5	1.6	2.8	1.1	1.0
	PAPER	3.2	1.1	1.8	1.2	1.1

DISCUSSION

From the results of the present series of experiments it can be concluded that paper delivery can be used as a response-contingent event for establishing and maintaining schedule-controlled patterns of responding in the hamster under a wide variety of experimental conditions. Characteristic schedule-controlled patterns of responding have been demonstrated for fixed-ratio, variable-interval, and differential reinforcement of low rate schedules of paper delivery (Figures 2, 3, 4, 5, and 7). Fixed-interval schedules of paper delivery did not consistently produce the positively accelerated, "scalloped" pattern of responding that is characteristic of fixed-interval schedules, but the behavior typically controlled by FI schedules was sometimes observed (Figure 6).

When progressive-ratio schedules of food and paper delivery were used to investigate the relative reinforcing strength of these two positive reinforcers, hamsters consistently responded to higher terminal ratios for food than they did for paper (Figure 12; Table 2). When hamster AW-3 was tested under a progressive-ratio 5 schedule for food delivery (Figure 13), an erratic pattern of responding occurred, with periods of high rate and low rate responding periodically alternating. No compelling explanation of this behavior can be offered at this time. However, since a progressive-ratio schedule of reinforcement does not discriminate between fast and slow rates of responding, it is possible that the schedule itself imparted some of the observed variability into this animal's performance. For example, both the slow run at point (a) in Figure 13 and the fast run at point (b) were reinforced in this session.

Finally, it was demonstrated that food deprivation was not a necessary condition for establishing and maintaining food-reinforced operant behavior in the hamster. Neuringer (1969) has previously demonstrated that both rats and pigeons will work for food in the presence of free food. In Neuringer's study it was necessary to food-deprive both species in order to establish the operant behavior in the animal's repertoire, but the behavior was later maintained in the presence of free food. Furthermore, the animals made fewer than 500 responses per day in the free-food condition. In the present study, hamsters responded at rates of approxinately 5,000 responses per hour in the presence of free food (Figure 8, top record). Thus the selection of an appropriate species is the only operation necessary to establish and maintain food-reinforced operant behavior.

Once it has been established that nesting material (paper) can serve as an effective positive reinforcer for the hamster, the question of why this is so then arises. In studying the complex interplay between organism and environment that characterizes the life-cycle of all mammalian species, it is often instructive to look for physiological features of the organism that have arisen in the course of evolution and that, in turn, influence the ways that the organism will react to its current environment. In the case of the hamster, it was noted in the Introduction that hamsters are known to hibernate. It is not an overstatement to suggest that hibernators spend much of their life either preparing for hibernation, hibernating, or recovering from hibernation, both behaviorally and physiologically. The connection between hibernation and the reinforcing properties of nesting material will now be proposed.

Since hamsters are mammalian hibernators, they are therefore not strictly classified as homeotherms. That is, hamsters sometimes regulate their body temperature like all mammals that are homeotherms, and use various physiological and behavioral mechanisms to insure a constant body temperature even in the face of large changes in ambient temperature. At other times, hamsters are functional poikilotherms, in that, under special conditions, their body temperature will rise and fall with changes in ambient temperature, and, at low enough temperatures, they will hibernate. Also, when the body temperature of a hibernating hamster approaches 0°C, another physiological mechanism of as yet unknown origin will gradually awaken a hamster over a two-or-three hour period, and this arousal mechanism prevents their death by freezing (Prosser & Brown, 1961, Ch. 9). The functional poikilothermy of hamsters that was noted above appears most reliably when three environmental factors converge to provide a triggering or releasing stimulus situation. These factors include a relatively low environmental temperature, coupled with the availability of both food and nesting material that can be hoarded (Deane & Lyman, 1954). Nesting material, for the hamster, appears to serve as a sort of "releaser" in eliciting or allowing physiological changes to occur in a manner analogous to the releasers that Lehrman (1965) has demonstrated in the courtship patterns of ring doves. In Lehrman's studies, environmental stimuli such as the sight of a conspecific dove trigger endocrine mechanisms to change in predictable ways. Thus nesting material, to the hamster, has both behavioral and physiological thermo-regulatory significance, and it is quite possible that, under conditions of only moderately low environmental temperatures such as in the present study (66° F. ±3°), a hamster with nesting material is physiologically different from one without it.

The physiological importance of a large supply of food would seem to be analogous to the significance of nesting material for the hamster. Since hamsters store food rather than becoming obese prior to hibernation, food has considerable significance for hamsters, beyond any immediate physiological need for it.

Two lines of evidence would suggest that food may be more important than nesting material for successful hibernation in the hamster. First Richards (1965), in studies of hamster nesting behavior, demonstrated that hamsters build nests up to a particular size, and then cease. He suggests that feedback from the nest itself controls the termination of nest building in hamsters. Thus there appears to be a "cutoff" mechanism for hamster nest building that has not been demonstrated in food-related behavior.

The other evidence for the relatively greater importance of food for hamsters comes from the present study. The progressive-ratio data especially indicate that superabundant food is a more effective reinforcer than nesting material for hamsters. This is not surprising, since a hibernating hamster awakens periodically to eat, and if the animal has an insufficien food supply it will die.

It is therefore apparent that evolution has produced behavioral and physiological mechanisms in hamsters related to hibernation, and that these mechanisms require that hamsters devote a considerable amount of time and energy to accumulating food. To be optimally efficient, the behavioral mechanisms should be relatively insensitive to local fluctuations in the abundance of food (deprivation or satiation) and this appears to be the case with hamsters (Figure 8). Thus the fact that hamsters are hibernating mammals can help explain some of the unusual findings of the present experiments, especially with reference to food-maintained behaviors.

Another feature of the present series of experiments that requires some elaboration is the use of operant conditioning techniques in the study of instinctive behaviors such as hamster nest building. The hamsters in these experiments have been engaging in what the ethologists have termed a "naturally occurring chain" sequence of behavior, with paper acquisition serving as the first link, and paper manipulating, piling, chewing, etc. representing the terminal link. The second link of the chain, commonly termed "nesting behavior", was freely available throughout this experiment. Consequently, the hamsters had an opportunity to engage in alternative behaviors (nesting) that were always concurrently available during the course of an experimental session, and frequent direct observations confirmed that the hamsters did engage in these and other nest-directed behaviors during periods of non-responding. These observations suggest that, with the appropriate apparatus, the behaviors of the second link of the chain might be brought under experimental control.

It appears that the schedule of paper delivery that is in effect determines how much nest-directed collateral behavior will be exhibited in a session, with fixed-ratio schedules producing considerably less disruptive nest-directed behavior that variable-interval schedules or DRL schedules. Thus the response rate engendered by a particular schedule of reinforcement is seen to exert a strong influence on how much disruptive behavior will appear in an experimental session.

It now appears that the data from the present experiments are relevant to both the methodology of comparative psychology, and to the cross-species aspects of the experimental analysis of behavior. With regard to comparative psychology, these experiments point to the advantages to be gained from automating the study of instinctive behavior. By using operant conditioning procedures and instrumentation it was possible to continuously monitor the acquisition of nesting material under many experimental conditions and over long periods of time. Kavanau (1967) has previously demonstrated that white-footed mice (Peromyscus) can master a very complicated experimental regimen that includes operant control of their feeding, drinking, gross activity, environmental illumination and access to the nest site. Operant control over nest material acquisition can now be added to the above list of behaviors, and interactions among all of these behaviors can be investigated.

The present experiments also have implications for the experimental analysis of behavior. On the most basic level, behavioral data have been gathered on the golden hamster, a species that has long been the subject of biomedical and physiological investigation, but that has been relatively ignored by behavioral scientists. Besides adding basic behavioral data on an unstudied species, and on a novel reinforcer (paper), the present experiments also extend the generality of the concept of "schedule-control of behavior". As replicable patterns of responding under a particular schedule of reinforcement are demonstrated in increasing numbers of species and with more reinforcers, the power of the concept of schedule-control of behavior will come to be more generally accepted among behavioral scientists.

By bringing the paper-maintained key pressing behavior of the hamster under schedule control one is, in effect, investigating a single link in a biologically important chain of events in the life of the hamster. Factors such as the current endocrine state of the hamster will interact with environmental factors such as temperature or schedule of reinforcement to determine the nature of the organism-environment interaction at any point in time. It is to be hoped that the present series of experiments can help point the way to elucidating the nature of the complex, "naturally occurring" chains of behavior that abound in the ethological literature.

In conclusion, an observation by Sidman (1960) would seem to be appropriate. He states:"What is not easily apparent, even to the educated and sympathetic nonscientist, is that the scientist is, primarily, seeking order in nature. Only the rare discovery turns out to be useful in a practical way. But the rare discoveries are usually built upon a foundation of small findings, none of them world-shaking in themselves, without which the final step could never have been taken. A major concern of science is the soundness of the basic edifice. . . Often, data are important only as they establish - or refute - the soundness of other data or of some conceptualization of natural phenomena. They serve to strengthen the internal consistency of the science; in this role they are fundamental to the advance of knowledge " (p.33).

It is hoped that the present data will add in some small part to our ever growing knowledge of the order to be found in behavioral phenomena.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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